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ANALYSIS OF GREEN TIME SEQUENCING AND OPTIMIZATION AT THE SIGNALIZED INTERSECTION OF JALAN W.R. SUPRATMAN–JALAN HASANUDDIN, TIMIKA CITY

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Abstract

Traffic performance at signalized intersections is strongly influenced by road geometry, traffic volume, and signal timing, particularly in urban transportation systems that frequently experience congestion and signal violations. This study analyzes the relationship between traffic capacity (passenger car unit per hour) and green time, and evaluates the sequence and duration of green time at the signalized intersection of Jalan Hasanuddin and Jalan W.R. Supratman in Timika City, Central Papua Province, Indonesia. Although the intersection is equipped with a traffic light control system (APILL), red-light running violations still frequently occur and increase the potential for traffic accidents. Field data on traffic volume, geometric conditions, and signal timing were collected through direct observation and analyzed using the Indonesian Highway Capacity Manual (MKJI 1997), supported by a review of recent international literature on signalized intersection performance, mixed motorcycle traffic behavior, and traffic signal optimization. The analysis reveals a nonlinear quadratic relationship between traffic capacity and green time, expressed as y = 1.165x2 − 9.2824x + 19.137, with a coefficient of determination (R2) of 0.9098, indicating a high level of model fit. Green time requirements decrease as capacity increases up to an optimal point, while lower capacities require longer green time due to less stable traffic flow. These findings support volume-responsive green time allocation as a strategy to improve intersection performance and reduce red-light violations.

Keywords: Green Time; Intersection Capacity; MKJI 1997; Signal Timing; Traffic Signal.

INTRODUCTION

The recognition of customary law communities is important not only in the context of cultural and legal diversity in Indonesia, but also the main door to optimize the protection of citizens' constitutional rights. The formulation of this The traffic performance of an urban road network is strongly influenced by road geometry, vehicle volume, and signal control at intersections. Congestion and traffic-rule violations are two persistent problems that consistently emerge in urban transportation systems, including in developing cities such as Timika. Studies in Addis Ababa, Ethiopia, for instance, show that congestion at major intersections generates substantial travel-time losses that directly affect the city's economic productivity (Sokido, 2024). Other research indicates that the individual cost of traffic congestion continues to rise alongside the growth of private vehicle ownership, making intersection performance optimization a priority in urban transportation planning (Nawaz et al., 2024).

Over the past several years, research on traffic signal optimization has progressed rapidly toward more adaptive, data-driven approaches. Various studies have developed signal control models coupled with connected autonomous vehicles (Wang, 2023), two-layer optimization frameworks that combine queue length with signal timing (Shen, 2024), and metaheuristic algorithms such as the adaptive artificial fish swarm algorithm for smart-city signal optimization (Wei & Ju, 2024). Multi-objective approaches based on the NSGA-III algorithm have also been applied to balance multiple performance indicators at signalized intersections within intelligent traffic networks (Zhang et al., 2023), while feedback queueing network models have been developed to capture congestion-propagation phenomena under dynamic, stochastic traffic conditions (Zhao et al., 2025). In mixed environments combining conventional and connected vehicles, the simultaneous optimization of vehicle trajectories and signal timing has also been examined to minimize energy consumption and delay (Zou et al., 2023), while the optimal cycle length for intersections with mixed pedestrian and bicycle traffic has been modeled analytically (Su et al., 2024). Although these approaches demonstrate significant progress, their implementation generally requires high-resolution detector data, connected-vehicle infrastructure, or computational capacity that is not yet widely available in medium-sized cities in developing countries. Analytical approaches based on the Indonesian Highway Capacity Manual (MKJI 1997) therefore remain relevant as a practical and well-established baseline method, particularly for intersections with fixed-time signal systems such as the one found in Timika City. The intersection between Jalan Hasanuddin and Jalan W.R. Supratman, located in Timika City, Central Papua Province, is equipped with a traffic light control device (APILL) that regulates vehicle and pedestrian movement. Despite the presence of this device, various violations and instances of red-light running still frequently occur at this intersection, potentially leading to accidents and even fatalities. Red-light running is not merely a local phenomenon; studies in various international contexts show that the severity of red-light violations is closely related to intersection delay, cycle length, and the duration of the yellow interval (Jalali Khalilabadi et al., 2023). The interaction between vehicles and pedestrians at signalized intersections is also a distinct source of safety risk, as demonstrated by studies on pedestrian crossing behavior in developing urban areas (Bayomi et al., 2024; Haque & Kidwai, 2023). These conditions provide an important reference point for evaluating traffic signal performance, particularly with respect to the sequencing and duration of green time for each phase at the intersection under study.

Theoretically, effective traffic signal control must account for traffic volume, approach capacity, and the distribution of vehicle flow across each intersection leg. Analytical methods as outlined in the Highway Capacity Manual emphasize the importance of calculating the degree of saturation and average delay as key indicators of intersection performance (Transportation Research Board, 2010). This basic concept of traffic flow at signalized intersections is also consistent with Traffic Flow Theory (Transportation Research Board, 2016; Oglesby & Hicks, 1999). In addition, signal-timing optimization approaches such as the Webster method are widely used to determine the optimal cycle and the allocation of green time (Webster, 1958), and to this day the formula remains a primary reference, even though numerous recent studies have proposed refinements based on high-resolution traffic data (Guadamuz et al., 2022), multi-objective frameworks that simultaneously consider pedestrian delay and vehicle emissions (Akyol et al., 2024), and microscopic simulation methods for unsignalized intersections used as a performance benchmark (Al-Rubaee & Hameed, 2024).

According to the Directorate General of Highways (MKJI, 1997), the three-color traffic light system—red, yellow, and green—is intended to separate the movements of vehicles arriving from opposing directions so that traffic flow at intersections can proceed in a more orderly manner. Traffic signals also serve to separate turning vehicles from pedestrians crossing the road, thereby reducing the potential for conflict and the congestion that arises from conflicting traffic streams during peak periods. Traffic characteristics in Indonesia, including in Timika City, are dominated by motorcycles, a pattern also found across many cities in Southeast Asia. The high proportion of motorcycles affects the saturation flow and discharge headway at signalized intersections (Suweda & Wedagama, 2021; Kariyana et al., 2021), the merging behavior of mixed traffic streams (Matcha et al., 2022), and the stopping behavior of motorcycle riders at signalized intersection approaches (Promraksa et al., 2022). A study in Bali further shows that the implementation of a motorcycle advanced stop box together with a countdown timer improves stopping discipline and reduces stop-line violations (Mulyadi et al., 2022a), consistent with findings that motorcycle rider safety on local roads is strongly influenced by rider age and riding behavior (Champahom et al., 2023), as well as findings on motorcycle positioning behavior within advanced stop boxes that affects traffic efficiency (Wichitphongsa et al., 2025).

Previous research shows that appropriate green-time adjustment can significantly improve intersection efficiency, reducing delay by 20–40% under certain conditions (Akçelik, 1981; Khisty & Lall, 2005). Analysis of the green-time sequence at the Jalan W.R. Supratman–Jalan Hasanuddin intersection is therefore important to determine whether the current signal setting is already optimal or still requires improvement. Much of the recent literature on traffic signal optimization focuses on intersection networks in large cities in developed countries or on artificial-intelligence-based simulation approaches, while empirical MKJI-based studies of medium-sized cities with high mixed-motorcycle traffic characteristics, such as Timika, remain limited. This gap forms the underlying motivation for the present study. Based on the background described above, this study aims to (1) analyze the pattern of traffic volume and passenger car units at the Jalan W.R. Supratman–Jalan Hasanuddin intersection; (2) analyze the relationship between traffic capacity and green time at the intersection; (3) evaluate traffic performance based on the technical parameters of MKJI 1997; and (4) provide recommendations for more efficient and safer signal settings to improve traffic flow and reduce the risk of red-light violations in the area.

2. LITERATURE REVIEW

2.1 Signal Timing and Green Time Optimization

Research on traffic-signal timing optimization originates from Webster's classical formula (1958), which computes the optimal cycle length based on the critical flow ratio of each phase. This formula subsequently became the foundation for various road-capacity analysis methods, including the Indonesian Highway Capacity Manual (MKJI, 1997) and the Highway Capacity Manual (Transportation Research Board, 2010). The development of high-resolution traffic-detection technology has enabled automatic, real-time measurement of green-time allocation efficiency, as introduced through green-time usage metrics at several intersections in Salt Lake City, United States (Guadamuz et al., 2022). This approach shows that green-time efficiency depends strongly on the alignment between signal-time allocation and the actual fluctuation of traffic volume for each movement. Contemporary research increasingly moves toward multi-objective optimization. Akyol et al. (2024) developed an optimization framework that considers the trade-off between pedestrian delay and vehicle emissions using the NSGA-II genetic algorithm, while Su et al. (2024) formulated an optimal cycle-length model for intersections with mixed pedestrian and bicycle traffic that affects vehicle saturation flow. Zou et al. (2023) integrated connected-vehicle trajectory control with fuzzy signal-timing optimization to minimize energy consumption, while Wei and Ju (2024) applied an adaptive artificial fish swarm algorithm for signal optimization at smart-city intersections. A multi-objective evolutionary algorithm approach (NSGA-III) has also been developed for signalized intersections within intelligent traffic networks (Zhang et al., 2023), and a two-layer framework combining multi-objective optimization with dynamic adjustment based on a fuzzy neural network has been proposed by Shen (2024). A coupled control model for traffic signals and connected autonomous vehicles has also been developed to make more efficient use of green time (Wang, 2023), while a feedback queueing network model has been used to capture congestion propagation across facilities at an intersection under stochastic and dynamic traffic conditions (Zhao et al., 2025). Overall, the research trend shows a shift from classical deterministic methods toward adaptive, granular data-driven approaches. However, most of these approaches require complex data-collection infrastructure (vehicle detectors, V2X communication, or monitoring cameras) that is not yet adequately available in many medium-sized cities, including Timika. This underscores the relevance of an empirical-analytical approach based on MKJI 1997, combined with regression analysis, as a bridge between classical methods and the data-driven optimization needs of developing-country contexts.

2.2 Characteristics of Motorcycle-Dominated Mixed Traffic

Traffic characteristics in Indonesia and most Southeast Asian countries are dominated by motorcycles, which exhibit riding behavior distinct from four-wheeled vehicles, thereby affecting saturation flow and capacity at signalized intersections. Suweda and Wedagama (2021) show that the proportion of motorcycles affects discharge headway and saturation flow at signalized intersections under mixed-traffic conditions, while Kariyana et al. (2021) modeled saturation flow based on motorcycle behavior during through movements at signalized intersections. The behavior of motorcycles at merging sections within mixed traffic streams has also been examined by Matcha et al. (2022), who found that the interaction between motorcycles and four-wheeled vehicles affects the effective capacity of intersection approaches.

The stopping behavior of motorcycle riders at signalized intersection approaches also affects traffic performance and safety. Promraksa et al. (2022) identified the factors influencing the stopping locations of motorcycle riders using unmanned aerial vehicle (UAV) observations in Thailand, while Wichitphongsa et al. (2025) modeled the filtering and stopping behavior of motorcycles at intersections equipped with advanced motorcycle stop boxes using microscopic simulation in Chiang Mai. The implementation of a motorcycle advanced stop box equipped with a countdown timer in Bali has been shown to improve motorcycle acceleration at the onset of the green phase and reduce stop-line violations (Mulyadi et al., 2022a), consistent with findings that rider age is a significant determinant of motorcycle crash severity on local roads, with young and older riders exhibiting different risk-factor patterns (Champahom et al., 2023). These findings are directly relevant to Timika City, which also exhibits a high proportion of motorcycles within its traffic stream, indicating that saturation-flow adjustment and green-time allocation must explicitly account for two-wheeled vehicle characteristics.

2.3 Safety, Violations, and Pedestrian Interaction at Signalized Intersections

Red-light running is among the highest-risk behaviors at signalized intersections. Jalali Khalilabadi et al. (2023) found that increased intersection delay and split failure are correlated with a higher frequency of violations, while longer yellow intervals and cycle lengths tend to reduce minor violations but may increase severe ones. This condition is relevant to the problem observed at the Jalan W.R. Supratman–Jalan Hasanuddin intersection, where red-light violations still frequently occur despite the presence of an APILL. Spatial analysis of traffic accidents using geographic information systems also shows that accident hotspots tend to concentrate at intersections with high traffic volume and signal settings that are less responsive to flow fluctuations (Hazaymeh et al., 2022).

The interaction between vehicles and pedestrians represents another important safety dimension. A study on road-crossing behavior in Cairo shows that crossing violations are associated with pedestrian behavioral factors and inadequate crossing infrastructure (Bayomi et al., 2024), while a statistical model based on artificial neural networks has been used to predict pedestrian behavior at signalized intersections in New Delhi (Haque & Kidwai, 2023). As a performance comparison, an evaluation of an unsignalized intersection using SIDRA software shows that a high degree of saturation at intersections without formal signal control produces substantially greater delay than an optimized signalized intersection (Al-Rubaee & Hameed, 2024), reinforcing the importance of appropriate signal settings at intersections such as the one examined in this study.

2.4 Congestion and Urban Mobility in Developing Cities

Traffic congestion in developing cities exhibits characteristics distinct from those in developed cities, primarily because the growth of motor-vehicle ownership is not matched by a corresponding increase in road-infrastructure capacity. A study in Addis Ababa shows that travel-time methods can be used to measure the level of congestion at major intersections as a basis for mitigation planning (Sokido, 2024), while research on individual congestion cost confirms that the economic impact of congestion is directly felt by private-vehicle users, underscoring the need for more responsive transportation policy (Nawaz et al., 2024). In the Indonesian context, an assessment of pedestrian-facility quality in Jakarta's central business district shows that improved walkability can help reduce dependence on private motor vehicles, which in turn may indirectly lower the traffic burden at signalized intersections in urban areas (Mulyadi et al., 2022b).

The synthesis of the literature reviewed above indicates that research on green-time optimization at signalized intersections has advanced rapidly toward adaptive, multi-objective, and granular data-driven approaches; however, empirical studies based on MKJI 1997 that specifically model the quantitative relationship between capacity and green time at intersections with high motorcycle-dominated mixed-traffic characteristics in medium-sized Indonesian cities—particularly in the Central Papua region—remain very limited. This study seeks to address that gap by developing a quadratic regression model of the relationship between capacity and green time at the Jalan W.R. Supratman–Jalan Hasanuddin intersection, Timika City, as an empirical contribution to the traffic-engineering literature for the region.

3. RESEARCH METHOD

3.1 Research Method

This study is a quantitative study employing the Indonesian Highway Capacity Manual (MKJI 1997), with reference to the Highway Capacity Manual (Transportation Research Board, 2010). The data used in this study consist of two types: primary and secondary data. Primary data were obtained through direct field observation, comprising traffic-volume counts, intersection geometric data, and signal data (phasing, green time, lost time). Secondary data were collected from various sources, including literature studies, previous research findings, and data from relevant agencies. The intersection of Jalan W.R. Supratman and Jalan Hasanuddin serves as the object of this study, in which analysis was conducted to examine the green-time sequence at that location. The study began with a literature review related to the research topic, including a review of 24 international journal articles indexed in Scopus and published within the last five years (2021–2025), as described in Section 2, providing a relevant theoretical framework and empirical benchmark. This was followed by problem identification, given that violations and potential accidents still frequently occur, necessitating an analysis of the green-time sequence in the area. The next stage involved the collection of primary data through field surveys and secondary data from relevant agencies, followed by data processing using the MKJI 1997 method to obtain values for capacity, degree of saturation, and other intersection performance parameters, which were then further analyzed to determine the relationship between capacity and green time.

3.2 Research Location

This study was conducted at the intersection of Jalan W.R. Supratman and Jalan Hasanuddin in Timika City, as shown in Figure 1.

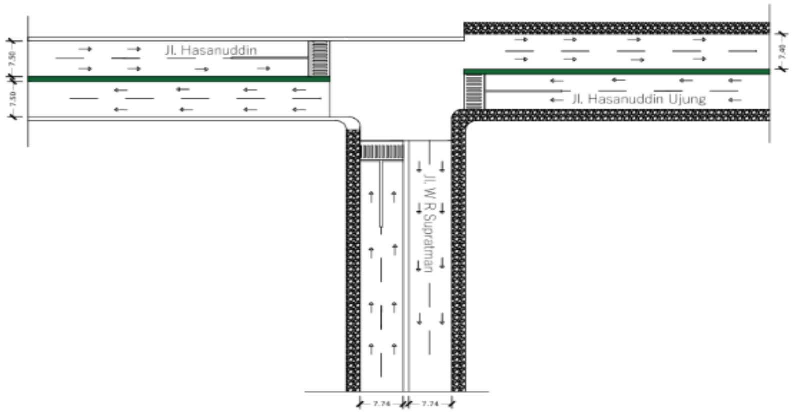

Figure 1. Sketch of the Research Location

3.3 Data Analysis Technique

Data analysis was carried out in several stages. First, the vehicle-volume data obtained from the survey were converted into passenger car units (PCU) using the passenger car equivalent (pce) factors specified in MKJI 1997, given that the high proportion of motorcycles in the traffic stream at the study location significantly affects saturation flow, as also found at signalized intersections with similar characteristics elsewhere in Southeast Asia (Suweda & Wedagama, 2021; Kariyana et al., 2021). Second, approach capacity (C) was calculated based on the base saturation flow (S0), geometric and environmental adjustment factors, and the green-time-to-cycle-time ratio (g/c), following the fundamental equations of MKJI 1997. Third, the degree of saturation (DS) was calculated as the ratio of traffic flow (Q) to capacity (C) for each approach. Fourth, a nonlinear (quadratic) regression analysis was performed between capacity (PCU/hour) as the independent variable and green time (seconds) as the dependent variable using the least-squares method, with the coefficient of determination (R2) used as the indicator of model fit. This regression approach is consistent with the principle of evaluating green-time efficiency based on empirical data, as developed by Guadamuz et al. (2022), and with the cycle-length optimization framework that accounts for variations in traffic conditions developed by Su et al. (2024).

4. RESULTS AND DISCUSSION

4.1 Traffic Volume

The chart in Figure 2 illustrates the vehicle volume observed over several survey time ranges, namely between 12:00 and 14:00, for each day of the week. In general, the number of vehicles tends to increase as the time progresses toward midday and into the early afternoon. On weekdays, i.e., Monday through Friday, vehicle volume is relatively stable, with a fairly narrow range across time intervals. Nevertheless, a slight increase is still observed during the period after 12:40 until around 13:40, indicating a rise in traffic activity as the lunch period draws to a close. Unlike weekdays, vehicle volume on weekends, particularly on Sundays, is considerably higher than on other days. On this day, a significant surge is observed across nearly all time ranges, with the peak volume occurring in the period approaching 14:00. Saturdays also show an increase compared with weekdays, although still below the volume observed on Sundays. This weekend increase is consistent with findings from other developing cities, where recreational activity and non-routine mobility on weekends are major contributors to peak traffic loads (Sokido, 2024), and also confirms that the congestion cost borne by private road users tends to increase during such periods (Nawaz et al., 2024).

Figure 2. Traffic Volume

Overall, this chart shows that the period between 12:40 and 14:00 constitutes the peak period, with the highest vehicle volume. A summary of the traffic-volume pattern by survey period is presented in Table 1.

Table 1. Summary of Traffic Volume Patterns by Survey Period

Survey Period	Day with Highest Volume	Main Characteristics
Morning (07:00–09:00)	Monday and Sunday	Fairly high volume associated with early-day activity (commuting to work/school and weekend recreation)
Midday (12:00–14:00)	Relatively uniform, rising toward 13:40	Relatively stable volume on weekdays, with a gradual increase
Afternoon (17:00–19:00)	Sunday (dominant), followed by Monday	Significant surge associated with the evening commute and weekend activity

In addition, the marked difference between weekdays and weekends indicates that public activity, particularly on Sundays, has a substantial influence on the increase in traffic volume at the W.R. Supratman–Hasanuddin intersection area.

4.2 Daily Passenger Car Units

The chart in Figure 3 shows the passenger car units per hour (PCU/hour) across several survey time ranges, from morning through afternoon, for each day of the week. In general, traffic volume fluctuates throughout the day, with distinct patterns across morning, midday, and afternoon periods. During the morning period (07:00–09:00), vehicle volume is already fairly high, particularly on Mondays and Sundays, reflecting early-day activities such as commuting to work, school, or other activities. Entering the midday period (12:00–14:00), vehicle volume tends to be more stable and lower than during certain morning or afternoon hours, although a gradual increase is still observed on several days, particularly toward 14:00. The most significant change occurs during the afternoon period, specifically between 17:00 and 19:00. During this time range, vehicle volume increases sharply, particularly on Sundays, which show the most dominant figures compared with other days. Mondays and several other weekdays also show a substantial increase, likely associated with the evening commute.

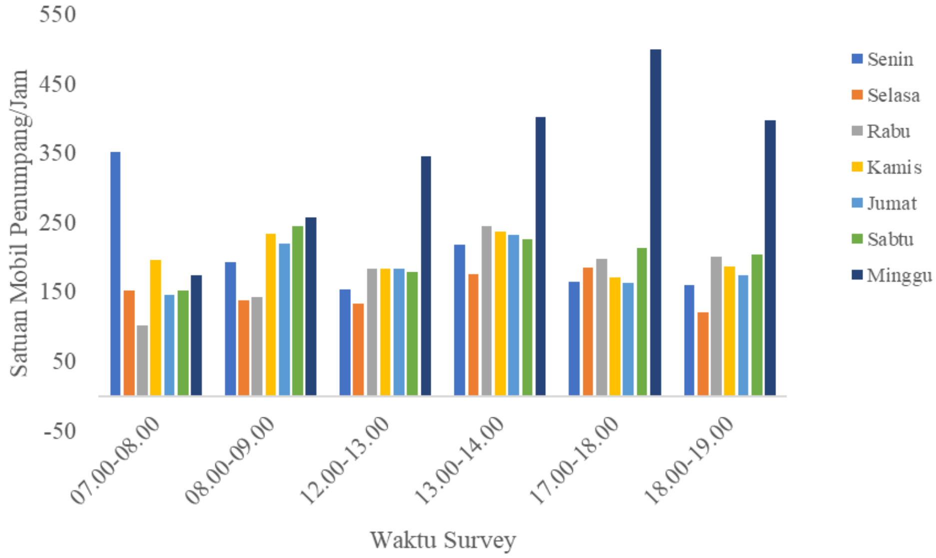

Figure 3. Daily Passenger Car Units

The conversion of mixed vehicle volume into PCU in this study is strongly influenced by the dominance of motorcycles in the traffic stream, a characteristic commonly found in Indonesian cities and Southeast Asia in general. Studies at signalized intersections under mixed-traffic conditions show that the shorter discharge headway of motorcycles compared with four-wheeled vehicles significantly affects the saturation flow value (Suweda & Wedagama, 2021), while saturation-flow modeling based on motorcycle behavior during through movements further confirms the need for a specific correction factor for two-wheeled vehicles (Kariyana et al., 2021). The interaction between motorcycles and four-wheeled vehicles at merging sections can also reduce the effective capacity of an approach if not properly managed (Matcha et al., 2022). Accordingly, the accuracy of the PCU values at the W.R. Supratman–Hasanuddin intersection also depends on the precision of the passenger car equivalent factors used, particularly for motorcycles, which dominate the vehicle composition at the study location. When compared across days, Sunday consistently shows the highest traffic volume, particularly in the afternoon, while weekdays such as Tuesday and Wednesday tend to have lower and relatively stable volumes. Overall, this chart shows that peak hours occur in the morning (07:00–09:00) and especially in the afternoon (17:00–19:00), with the highest peak occurring on weekends, particularly Sunday, reflecting the increased mobility patterns of the public during these periods.

4.3 Green Time

Figure 4 illustrates the relationship between traffic capacity (PCU/hour) and green time at the signalized intersection under study, which is closely related to the analysis of green-time sequencing and allocation. Descriptively, the chart shows a nonlinear (quadratic) relationship between capacity and green time, as expressed by the following regression equation.

$$y = 1.165x2 - 9.2824x + 19.137, \text{ with } R2 = 0.9098 \quad (1)$$

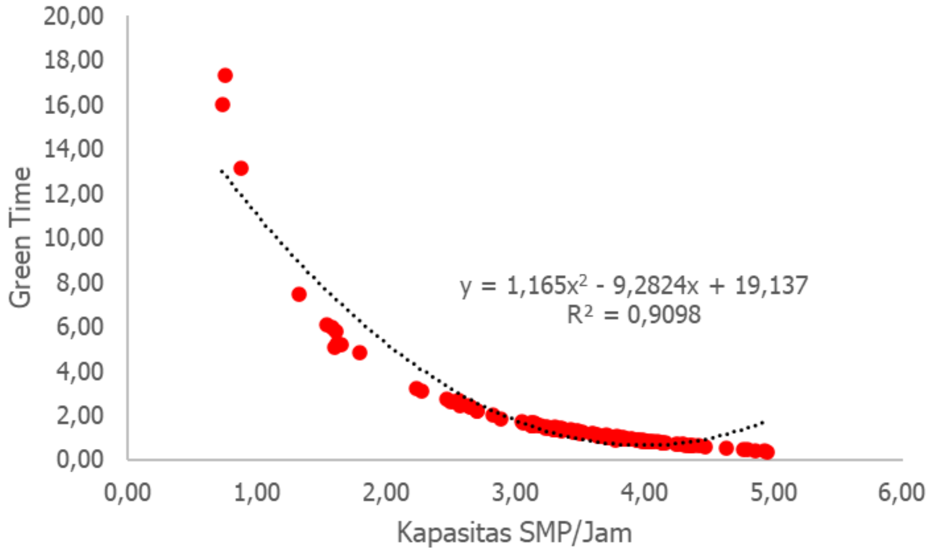

Figure 4. Relationship between Capacity and Green Time

The high R2 value of 0.9098 indicates that the model fits the relationship between the two variables reasonably well. This level of model fit is comparable to that achieved in various recent data-driven signal-optimization studies; for instance, the evaluation of green-time allocation efficiency using high-resolution traffic data likewise shows that volume fluctuations across phases can be systematically explained through similar quantitative metrics (Guadamuz et al., 2022). From the scatter pattern, it can be observed that as capacity (PCU/hour) increases, the required green time decreases, up to a certain minimum point. This indicates that under high and efficient traffic flow, green-time allocation can be shortened because the vehicle flow tends to be more stable and orderly.

Conversely, at lower capacities, the required green time tends to be greater. This condition typically occurs because vehicle flow is less orderly, requiring longer green time to safely accommodate vehicle movement. This quadratic relationship pattern is consistent with the principle of cycle-length optimization that accounts for variations in traffic-flow conditions and vehicle composition (Su et al., 2024), and aligns with findings that volume-responsive green-time allocation can improve efficiency without compromising pedestrian safety or excessively increasing vehicle emissions (Akyol et al., 2024).

The empirical regression-based approach used in this study operates at a simpler technological level compared with adaptive approaches based on metaheuristic algorithms (Wei & Ju, 2024), NSGA-III-based multi-objective optimization (Zhang et al., 2023), or connected-autonomous-vehicle signal control (Wang, 2023; Zou et al., 2023). Nevertheless, the resulting quadratic model retains high practical value, as it can be directly applied by field traffic operators without requiring complex sensor infrastructure, while also serving as a quantitative foundation for the development of more adaptive systems in the future, including two-layer frameworks that combine static optimization with dynamic adjustment (Shen, 2024) and feedback queueing models for capturing congestion propagation at high-volume intersections (Zhao et al., 2025).

4.4 Safety Implications and Recommendations

The finding of a quadratic relationship between capacity and green time has direct implications for the red-light violation problem that continues to occur at the Jalan W.R. Supratman–Jalan Hasanuddin intersection. When green time is not proportional to actual volume, drivers tend to experience excessive delay during the red phase, which, according to international studies, can increase the likelihood of red-light running, particularly under conditions of high intersection delay and split failure (Jalali Khalilabadi et al., 2023). Spatial analysis of accident hotspots further confirms that intersections with signal settings less responsive to flow fluctuations are at risk of becoming accident-concentration locations (Hazaymeh et al., 2022). Accordingly, the implementation of volume-responsive green-time allocation, as indicated by the regression model developed in this study, has the potential to reduce violation frequency while improving intersection safety. From the standpoint of pedestrian interaction, improvements to crossing facilities and the provision of dedicated pedestrian phases warrant consideration, given that studies in other developing cities show that inadequate crossing infrastructure contributes to risky crossing behavior (Bayomi et al., 2024) and that predictive models based on pedestrian behavior can assist in designing safer signal phasing (Haque & Kidwai, 2023). Given the high proportion of motorcycles at the intersection under study, the implementation of a motorcycle advanced stop box equipped with a countdown timer, as proven effective in Bali (Mulyadi et al., 2022a), together with the design of advanced stop boxes that account for motorcycle filtering behavior (Wichitphongsa et al., 2025), can serve as an additional technical recommendation to improve stopping discipline and reduce stop-line violations at the W.R. Supratman–Hasanuddin intersection. As a performance comparison, an evaluation of an unsignalized intersection using SIDRA software shows that, without optimal signal control, the degree of saturation and delay can increase dramatically (Al-Rubaee & Hameed, 2024), confirming that the presence of an APILL at the W.R. Supratman–Hasanuddin intersection remains essential, although its effectiveness depends heavily on the accuracy of green-time settings. In the long term, given the growth trend of motor vehicles and congestion patterns observed in similar developing cities (Sokido, 2024; Nawaz et al., 2024), further research is also needed to move toward an adaptive signal system based on real-time volume data, as has been developed at various intersections in other cities (Wei & Ju, 2024; Zhang et al., 2023; Shen, 2024; Zhao et al., 2025), as a continuation of the basic quadratic model developed in this study.

5. CONCLUSION

This study shows that the relationship between traffic capacity and green time at the signalized intersection of Jalan W.R. Supratman–Jalan Hasanuddin, Timika City, is nonlinear and quadratic, expressed by the equation $y = 1.165x2 - 9.2824x + 19.137$ with a coefficient of determination $R2 = 0.9098$, indicating a high level of model fit. As capacity increases, the required green time tends to decrease up to an optimal condition, whereas lower capacities require greater green time. This confirms that green-time allocation must be proportionally adjusted to the magnitude of traffic flow rather than fixed. This principle is consistent with the guidance in the Highway Capacity Manual, which states that signal-time allocation must be based on volume and capacity to achieve optimal intersection performance (Transportation Research Board, 2010), and is consistent with various recent literature findings on the importance of volume-responsive green-time allocation at signalized intersections (Guadamuz et al., 2022; Su et al., 2024; Akyol et al., 2024).

The traffic-volume pattern shows that the afternoon period (17:00–19:00), particularly on Sundays, constitutes the period of highest traffic load, while the dominance of motorcycles in vehicle composition affects the passenger-car-unit values and saturation flow at the intersection under study, consistent with the mixed-traffic characteristics commonly found in Indonesian and Southeast Asian cities (Suweda & Wedagama, 2021; Kariyana et al., 2021; Matcha et al., 2022; Promraksa et al., 2022). The ongoing problem of red-light violations at this intersection is consistent with international literature findings that high intersection delay and less responsive signal settings contribute to increased violations and accident risk (Jalali Khalilabadi et al., 2023; Hazaymeh et al., 2022).

Based on these findings, it is recommended that Timika City's traffic authorities consider volume-based green-time adjustment at the W.R. Supratman–Hasanuddin intersection, the implementation of a motorcycle advanced stop box with a countdown timer, and improvements to pedestrian crossing facilities. Future research is recommended to develop predictive models that incorporate multi-period volume data over longer time frames, explicitly integrate motorcycle and pedestrian safety factors, and explore the implementation of adaptive signal control systems as developed in various contemporary studies (Wang, 2023; Shen, 2024; Wei & Ju, 2024; Zhang et al., 2023; Zhao et al., 2025), as a continuation of the MKJI 1997–based foundational model developed in this study.

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